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Applying the open innovation system concept to infrastructure projects

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ABSTRACT

Purpose: The goal of this conceptual paper is to provide tools to help maximise the value delivered by infrastructure projects, by developing methods to increase adoption of innovative products during construction.

Methods: The role of knowledge flows in determining innovation adoption rates is conceptually examined. A promising new approach is developed. Open innovation system theory is extended, by reviewing the role of three frameworks: (1) knowledge intermediaries, (2) absorptive capacity and (3) governance arrangements.

Originality: We develop a novel open innovation system model to guide further research in the area of adoption of innovation on infrastructure projects. The open innovation system model currently lacks definition of core concepts, especially with regard to the impact of different degrees and types of openness. The three frameworks address this issue and add substance to the open innovation system model, addressing widespread criticism that it is underdeveloped.

The novelty of our model is in the combination of the three frameworks to explore the system. These frameworks promise new insights into system dynamics and facilitate the development of new methods to optimise the diffusion of innovation.

Practical Implications: The framework will help to reveal gaps in knowledge flows that impede the uptake of innovations. In the past, identifying these gaps has been difficult given the lack of nuance in existing theory. The knowledge maps proposed will enable informed policy advice to effectively harness the power of knowledge networks, increase innovation diffusion and improve the performance of infrastructure projects. The models developed in this paper will be used in planned empirical research into innovation on large scale infrastructure projects in the Australian built environment.

Keywords: innovation, absorptive capacity, infrastructure projects, construction industry, built environment

Theme: Knowledge-based urban development

INTRODUCTION

This is a conceptual paper that discusses tools that might usefully be employed to enhance the performance of large scale infrastructure projects, as a means of improving returns on investment in establishing a more effective built environment. The paper focuses on the role of innovation in supporting improved project outcomes. In this respect it is important to consider both innovation typologies and innovation processes. Models of both are developed here. It is intended that these models be employed in understanding innovation on infrastructure projects. It is expected that their use will result in more effective policy advice, than that which more piecemeal approaches would yield. Planned future empirical research will test their practical value.

Interest in the subjects described above has been driven by the poor state of civil infrastructure in Australia’s built environment.

EMPIRICAL BACKGROUND

After more than 20 years of underspending, Australia's infrastructure is considered to be in crisis. A landmark report by CEDA (Committee for Economic Development of Australia) identified problems across many infrastructure types, including land transport, sea and air ports, energy and water (CEDA, 2005). Deficiencies have also been identified in social infrastructure such as hospitals and schools (Argy, 2008). The aging of existing infrastructure is a key issue constraining Australia's potential economic growth (CEDA, 2005; BCA, 2007; Coombs & Roberts, 2007). The CEDA report diagnosed a 'deep seated infrastructure delivery problem' stemming from declining real infrastructure investment nationally since the 1980s. Economic production is compromised by these problems, as infrastructure is the foundation for other productive processes. Infrastructure reduces transaction costs and enhances the opportunities for access and exchange.

Acknowledging the problems, some governments have launched large infrastructure building programs, particularly in those states impacted by spiralling resource exports, Queensland and Western Australia. International comparisons rank Australian investment fourth highest in the world, by the value of construction deals at all project stages (Infrastructure Journal Online, 2008). According to major investor ABN Ambro, $380-455 billion worth of investment is needed over the next decade (Hepworth & Connors, 2008). Although current economic uncertainties may slow government plans, in the long run significant infrastructure investment cannot be avoided, as it is the basis of all productive activity. Certainly policies developed prior to the current financial crisis indicate massive investment (NSW Treasury, 2008; Qld Government, 2008; Rudd, 2008; Vic Government, 2008; WA Government 2008), and as infrastructure investment is often employed counter-cyclically to promote economic growth, investment may grow rather than fall. In any event, the scale of projected infrastructure investment over the next 20 years is unprecedented in Australia's history, and is presenting significant delivery challenges. The framework presented here responds to these challenges. It will be used in later research to address infrastructure delivery problems, largely related to limited capacity and underperformance on projects with regard to time, cost, quality and environment. The framework responds to these industry concerns, by providing the means to deliver information on which to base strategies to (1) increase the efficiency of infrastructure projects (2) improve project outcomes and (3) improve the capacity of the construction industry.

Innovation in the operation and delivery of infrastructure projects can add considerable value to government investments.

CONCEPTUAL BACKGROUND

This section discusses innovation typologies and innovation processes, as background to interpreting an optimal approach for assessing such knowledge and packaging it in a way that will result in useful policy guidance within the infrastructure development space.

Innovation Typologies

The literature reveals increasing sophistication in the characterisation of different types of innovation, from simple distinctions between product and process innovation to more detailed categories along an expanding set of dimensions. New typologies categorise innovations based on implementer’s control, output class, degree of novelty, knowledge characteristics, system linkages, decision making, and source of idea (Teece, 1986; W. Powell, 1991; Rothwell, 1994; Winch, 1998; Mitropoulos & Tatum, 1999; Slaughter, 2000; Gopalakrishnan & Bierly, 2001; Harty, 2005; Organisation for Economic Cooperation and Development OECD/Eurostat, 2005). Table 1 summarises key innovation typologies in the literature.

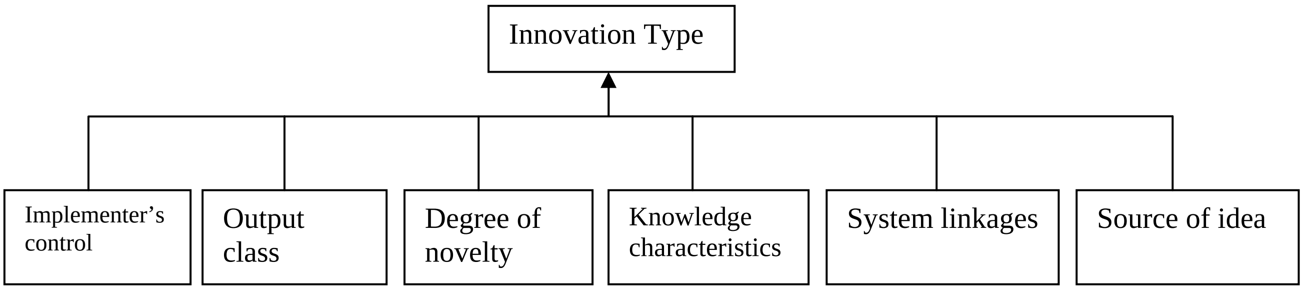
Table 1: Key innovation typologies

Author(s)	**Based on …**	**Categories**
Harty (2005)	Implementer’s control	**Bounded** – innovation implementation can be contained within a single sphere of influence **Unbounded** – innovation implementation takes place in more contested domains
OECD (2005)	Output class	**Product** – good or service **Process** – production or delivery method **Marketing** – packaging, placement, pricing **Organisational –** internal business practices The intention is that these OECD categories are mutually exclusive and that they cover all possible types of innovation output by firms. Product and process innovation tends to be technical/technological in character.
OECD (2005)	Degree of novelty	**New to the firm** – lowest degree of novelty – innovation adopted from within the industry **New to the industry** – innovation adopted from another industry **New to the world** – highest degree of novelty – previously unseen innovation – likely to be patented if technological in nature
Gopalakrishman and Bierly (2001)	Knowledge characteristics	**Tacit/Explicit –** codifiability, teachability, observability, articulateness **Systemic/Autonomous –** extent to which knowledge components are linked with other components **Complex/Simple** – sophistication of knowledge [last two dimensions reflect Slaughter 2000]
Slaughter (2000)	Change in knowledge and change in system linkages (System linkages first addressed by Teece 1986).	**Incremental** – small change in knowledge and small system impact **Architectural** – small change in knowledge and large system impact **Modular –** large change in knowledge and small system impact **System –** large change in knowledge from a combined set of innovations and large system impact **Radical –** large change in knowledge and new system
Mitropoulos and Tatum (1999)	Decision making (Similar to Winch 1998).	**Strategic –** continuous monitoring of ideas, thorough evaluation of options, top management participation, seeking to maximise benefits [proactive innovation] **Project –** solution driven innovation, limited evaluation of available options, seeking to minimise consequences of failure [reactive innovation]
Winch (1998)	Source of idea	**Top down** – new idea adopted by firms’ managers and implemented on projects [proactive innovation] **Bottom up** – new idea is the result of problem-solving on construction sites, which may be later learned by the firm [reactive innovation]
Teece (1986)	System linkages	**Autonomous** – little system impact **Systemic –** large system impact

Source: (K. Manley, 2008b)

Understanding innovation characteristics along these dimensions has the potential to assist policy making to improve innovation adoption on infrastructure projects. Figure 1 summarises the above information in the form of a model.

Figure 1: A model defining innovation type



It is useful for policy makers to understand the different types of innovations that may be employed on infrastructure projects. This knowledge helps frame understanding of the conditions necessary for innovation. Even more information is given in this respect by considering the dynamic processes underlying innovation. Hence, at a broader level of analysis, there is another vast set of literature focused on interactive innovation *processes*.

Innovation processes

Technological and social advancements have resulted in the need for new forms of organisation for successful innovation. In the past, innovation processes may have been effectively managed by individual firms, however this is no longer true. Successful innovation is increasingly seen to be the result of a team effort between a collective of industry players. Interactive innovation processes lie at the heart of business success in the new economic circumstances. As the Bureau of Industry Economics noted as early as 1991 (p. 7):

> For some time, studies of the innovation process have stressed the importance of networks to successful innovation, over-turning the traditional model which characterises innovation as a linear sequence running from basic research, through product development, to production and marketing. Innovation is now seen as an interactive process requiring intense traffic in facts, ideas and reputational information within and beyond the firm.

It is now clear that innovating firms 'cannot be analysed in isolation: innovation capability depends in fact also on the amount of information that each firm is able to receive from the environment in which it operates' (Antonelli, 1996, p. 284). This interactive view of innovation is the basis for many conceptual elaborations of the innovation process, all of which emphasise the increasing complexity of successful innovation and the importance of external knowledge sources. There has been considerable activity in developing new approaches to understanding contemporary innovation processes. However, the breadth of alternatives can be bewildering for entrepreneurs and policy makers seeking practical guidance. In response, the literature was reviewed with the intention of identifying common themes (K. Manley, 2003). Four key approaches to understanding interactive innovation processes were found: systems (Freeman, 1987; Nelson, 1993; Edquist, 2005; Lundvall, 2007), networks (DeBresson & Amesse, 1991; Freeman, 1991; W. Powell, Grodal, S. , 2005), value-chains (Von Hippel, 1988; Normann & Ramirez, 1993; Marceau, 1995; Jacobides, 2006) and clusters (Porter, 1998; Tan, 2006).

These frameworks are the most distinctive and have the highest profile in the academic and business literature. Encompassing these four, the idea of open innovation systems has emerged over the last few years. This concept is being referenced in the literature with increasing frequency. As an overarching model, it very usefully draws attention to the key feature of modern innovation processes – their openness to external ideas. Yet, as will be shown, the open innovation system concept can be made more useful still, by integrating its use with three related models that focus more specifically on crucial aspects of open innovation systems. These three models explicate these aspects in a dedicated and comprehensive fashion. The models pertain to (1) knowledge intermediation, (2) absorptive capacity and (3) governance arrangements. These models address the emphasis within open innovation systems on the ease of knowledge flows, and the role of the absorptive capacity of stakeholders in adding value to such knowledge, mediated by the governance context in which those stakeholders operate.

THE OPEN INNOVATION SYSTEM MODEL

The open innovation system concept has grown out of the work of authors such as Rothwell (1994), Chesbrough (2003) and Gassmann (2006). Policy makers have been using it over the past five years to promote greater collaboration between firms (Dahlander & Gann, 2008). The concept is simple to understand and persuasive in its call for greater openness to external ideas, in the name of creativity, innovation and growth (K. Manley, 2001a). It is a highly appropriate model for examination of knowledge flows in large scale infrastructure projects. The open innovation system concept has mostly been applied to high-technology sectors. As an extension to the current knowledge base, future empirical work by the authors will apply an enhanced version of the concept to a more mature sector – the construction industry, in an examination of the infrastructure delivery phase of urban development.

A review of the literature on open innovation systems shows that the three crucial aspects of its operation pertain to knowledge intermediation, absorptive capacity and governance arrangements. Development of these aspects will provide new insights into system dynamics and facilitate new methods to optimise the diffusion of innovation. The three frameworks add substance to the open innovation system concept, addressing widespread criticism that it is underdeveloped (Gassmann, 2006; Dahlander & Gann, 2008; Dodgson & Steen, 2008).

Knowledge Intermediation

Knowledge intermediation occurs when there are knowledge flows from knowledge production organisations (including manufacturers) to knowledge users (including project-based firms). The organizations that facilitate these flows, the knowledge intermediaries, are an essential component of knowledge networks (Mowery & Shane, 2002). Intermediaries provide a search function to identify technology and knowledge solutions, matching knowledge suppliers and users (Howells, 2006: 216-217). Intermediaries are particularly important in facilitating market-pull knowledge transfer (Markman, Phan, Balkin, & Gianiodis, 2004), an aspect that is important in the context of infrastructure projects. Project-based forms of organization are increasingly prominent, but have been neglected in research. The planned empirical work will be the first substantive study of knowledge intermediation in a project-based context.

Absorptive Capacity

Absorptive capacity is the ability of an economic actor to absorb ideas from its environment. It has been usefully conceptualised as a dynamic capability relating to knowledge creation and utilisation (Zahra & George, 2002). Absorptive capacity is a ubiquitous concept in the general management literature, yet it has only guided one previous study in the construction industry context (D. Gann, 2001). Given the promise of the framework (Wesley Cohen & Levinthal, 1989; W. Cohen & Levinthal, 1990), it is time to apply it more extensively to this context. The planned empirical work on infrastructure projects will examine three primary components of absorptive capacity (1) exploratory learning (2) transformative learning and (3) exploitative learning (Lane, et al., 2006).

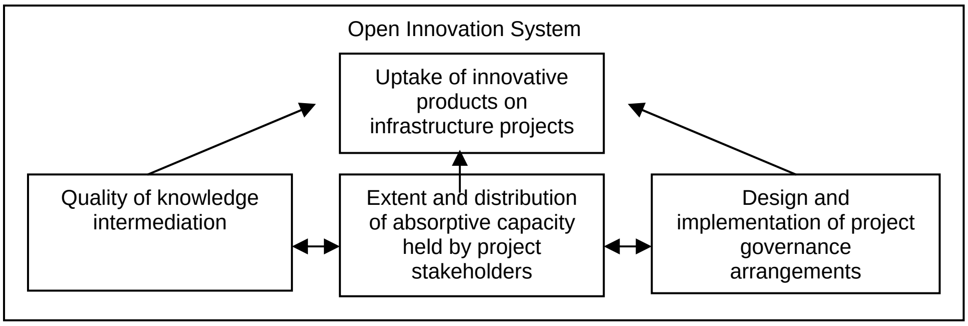
A recent authoritative review of absorptive capacity theory (Lane, et al., 2006) has called for research in a few target areas, many of which will be addressed in the planned study of infrastructure projects: (1) *More substantive investigations of absorptive capacity* –absorptive capacity is a key aspect of the planned study, (2) *Tests of absorptive capacity in non R&D intensive contexts* – the planned study explores absorptive capacity in the construction industry context, which is a relatively low-technology sector, (3) *Metrics that capture the individual components of absorptive capacity* – the planned study will assess the status of the three components across different actor types, and (4) *Exploration of associated processes* – the planned study will look at how knowledge intermediation and governance arrangements shape absorptive capacity over time.

Governance Arrangements

Governance arrangements affect innovation by influencing the way economic actors coordinate decision making and share knowledge (Ring, Bigley, D'Aunno, & Khanna, 2005). Recent work shows that governance models vary on two key dimensions (Parker, 2008). The first is the institutional context of economic decision making; the second is the way economic activity is structured by incentives/disincentives to motivate economic behaviours, such as knowledge sharing and collaboration. Networks, rather than hierarchies, are emphasised in the governance literature, recognising that decentralised decision-making processes are required to cope with rapid social change, societal complexity and instability (Castells, 1996; Williamson, 1996; Jessop, 2002). The planned empirical study will extend existing research by applying general management insights on governance to project-based production, in the large scale infrastructure context.

The theoretical approach described above and shown in Figure 2 will be used in future empirical work to guide data collection and analysis to map the open innovation system for infrastructure delivery in the Australian built environment sector. The models developed in this paper potentially have much broader applicability and can be applied to multi-level qualitative studies, covering firms, sectors, states and overall systems.

Figure 2: A model extending the open innovation system concept



THE PLANNED EMPIRICAL STUDY

A team of researchers from Australian universities have won funding from the Australian Research Council to apply the above models to a large scale study of new product adoption on large scale road and bridge projects. The study will run from 2010 to 2013. The goal of the study is to maximise the value of Australia's infrastructure investment plans, by developing methods to increase adoption of innovative products during construction. The study address a costly practical problem – inadequate uptake of innovation on infrastructure projects – and a constraining theoretical problem – the absence of integrated construction/general management approaches to infrastructure project delivery. There are three key research questions:

Research Question 1	**Research Question 2**	**Research Question 3**
How do knowledge intermediaries link innovative products to infrastructure projects?	How are the three components of absorptive capacity – exploratory, transformative and exploitative learning – distributed among the six construction sectors?	How is the level and distribution of project absorptive capacity influenced by different governance arrangements?

The study will be significant because the topic has not been explored before. Manufacturers are a key source of product innovation on building and construction projects (M. (1960) Bowley, 1960; M. Bowley, 1966; D. Gann, 2001; Larsson, Sundqvist, & Emmitt, 2006). Yet apart from previous work by Manley (K. Manley & Marceau, 2002; K. Manley, 2008a), there has been no significant empirical study exploring the role of knowledge flows in enabling greater adoption of innovative products. Existing literature on pre-assembly systems (Barlow, et al., 2003; Blismas, et al., 2006) and supply-chain integration (Hinze, 1994; D. M. Gann & Salter, 2000; London, 2001) provides input to the planned study, but does not address the problem of inadequate adoption of new products on infrastructure projects.

CONCLUSIONS

The models developed in this paper are significant because they extend disciplinary knowledge in general management and in construction management, by arming the open innovation system concept with the teeth to really investigate real world issues, such as that described above. The integrated open innovation system model developed here will help to reveal gaps in knowledge flows that impede the uptake of innovations. In the past, identifying these gaps has been difficult given the lack of nuance in existing theory. The knowledge maps generated by the new model will enable informed policy advice to effectively harness the power of knowledge networks, increase innovation diffusion and improve the performance of infrastructure projects. The model is expected to have greater diagnostic power than those currently in use, advancing the theory of innovation and construction innovation. Further, with national economic development dependent on infrastructure projects of increasing size and complexity, there is an imperative to apply these conceptual innovations to maximise the potential for adoption of construction innovations in this new context.

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